

### REMARKS

Claims 12 and 27 have been amended as set forth above in order to maintain consistency of language with claim amendments made in applicants' previous Amendment "A".

The amendments to the claims set forth above are fully supported by the specification and drawings as originally filed.

Applicants would like to mention that the amendments to the claims set forth above are made solely for the purpose of correcting formal matters, and in no way should be construed as agreement with or acquiescence to the Examiner's grounds for rejection of the claims.

Claims 8 - 27 are presently pending in the application. Applicants will address the Examiner's rejections as they relate to the presently pending claims, as amended above.

### Claim Rejections Under 35 USC § 103

Claims 8 - 17 are rejected under 35 USC § 103(a) as being unpatentable over Gelatos et al. in view of Landers et al.

As described in applicants' Summary of the Invention at Specification Page 5, lines 12 - 19, applicants discovered that  $\text{TaN}_x$  (tantalum nitride) provides a better barrier layer than Ta (tantalum). However, copper deposited directly over  $\text{TaN}_x$  does not exhibit a sufficiently high degree of  $\langle 111 \rangle$  crystallographic content to provide the desired copper electromigration characteristics. To provide both a barrier to the diffusion of copper into underlying layers and to enable the formation of a copper layer having the desired  $\langle 111 \rangle$  content, it is necessary to first deposit a barrier layer of  $\text{TaN}_x$  and then deposit a wetting layer of Ta over the layer of  $\text{TaN}_x$ , followed by deposition of an overlying copper layer.

As further described at Page 6, lines 14 - 17, since the crystal orientation of the copper is sensitive to deposition temperature, it is important that the maximum temper of the copper either

during deposition or subsequent annealing processes is less than about 500 °C, and preferably is about 300 °C.

Gelatos et al. discloses a three-layer "interface layer" structure which overlies the surface of a dielectric layer and comprises, from bottom to top, a first layer of titanium, a second layer of titanium nitride, and a third layer of titanium (Abstract, lines 9 - 12). Although Gelatos et al. suggests that other metals having the necessary adhesive and diffusion barrier characteristics can be employed to form the interface layer, the example provided is the use of titanium or tungsten or tantalum in place of titanium nitride as a diffusion barrier layer, and the use of chrome as the upper metal layer of the interface layer (Col. 3, lines 53 - 60). This is in contrast with applicants' teachings that tantalum does not provide an adequate barrier layer and that tantalum should be used as an upper (wetting) layer to interface with the depositing copper.

The emphasis in Gelatos et al. is in creating a copper-titanium intermetallic layer to provide adhesion of the copper layer to the underlying titanium nitride layer (Col. 5, lines 14 - 43). In order to create the copper-titanium intermetallic layer, Gelatos et al. uses an annealing step. The annealing step is carried out at reduced pressure and at a temperature of about 500 - 600°C (Col. 5, lines 26 - 28). As described in applicants' previous Amendment "A", copper adheres better to tantalum, so there is no need to form a copper-tantalum intermetallic layer, and no annealing step is required.

The Examiner states that ". . . Gelatos is cited to teach a substrate temperature of less than 500°C such as found within the disclosed range of 400°C to 500°C (Col. 5 line 39)." Gelatos et al. teaches that annealing may be carried out at a lower temperature of about 400°C to about 500°C only in the presence of a forming gas (N<sub>2</sub>H<sub>2</sub>), and that this is a less preferred alternative to simple annealing at 500 °C - 600 °C, at reduced pressure. Gelatos et al. does not recognize any advantage to use of the lower temperature range. Gelatos does not even suggest that the electromigration characteristics of the copper will be affected by the annealing temperature. Gelatos et al. teaches away from the present invention.

Landers et al. discloses a chemical mechanical planarization method for selectively removing a layer of metallization material, such as tungsten or copper, and a liner film, such as Ti/TiN or Ta/TaN, from the surface of an oxide layer of a semiconductor wafer. At Col. 1, lines 38 - 43, Landers et al. states: "A thin liner film, generally not more than approximately 1,000 Angstroms thick is then deposited over the oxide layer. The liner generally comprises thin films of titanium (Ti) and titanium nitride (TiN) disposed over one another to form a Ti/TiN stack, or tantalum (Ta) and tantalum nitride (Ta<sub>N</sub>) to form a Ta/TaN stack." The Examiner states that "As further evidence that Ti/TiN and Ta/TaN are obvious variants over one another, Landers is relied upon to teach that both Ti/TiN and Ta/TaN layers are well known as barrier layers and are art-recognized equivalents in regards to functioning as an underlying refractory metal layer for a subsequent deposition."

However, as previously described, it is not a question of whether one material can be substituted for another, but whether the desired device behavior properties will be achieved when a substitution is made. For example, the above description taken from Landers et al., Col. 1, lines 38- 43, clearly indicates that the upper barrier layer composition which will be in contact with a tungsten or copper wiring layer is a nitrogen-containing layer. Applicants determined that although a TaN<sub>x</sub> layer made a good barrier layer, copper deposited over this TaN<sub>x</sub> layer did not have the desired <111> crystallographic content and therefore had inferior electromigration resistance. The Ta layer must be the layer in contact with the copper layer. There is nothing in Landers et al. which teaches or even suggests that a Ta layer must be in contact with the copper layer, so that electromigration characteristics of the copper layer will be better. As discussed in applicants' previous Amendment "A", the order of deposition of the tantalum nitride and tantalum is a critical feature of applicants' claimed method.

Gelatos et al. teaches that tantalum may be used as a barrier layer with an overlying layer of titanium or chrome, where the titanium or chrome is in contact with an overlying copper layer. Landers et al. describes a barrier layer where TiN<sub>x</sub> or TaN<sub>x</sub> is in contact with an overlying layer of

tungsten or copper. A combination of these teachings will not lead one skilled in the art to applicants' invention where a  $TaN_x$  layer is used as the barrier layer, but a Ta wetting layer is deposited over the barrier layer so that a depositing copper layer contacts the Ta wetting layer surface and a desired  $\langle 111 \rangle$  crystallographic content is obtained in the copper layer. Whether taken alone or in combination, the disclosures of Gelatos et al. and Landers et al. neither teach nor suggest applicants' claimed invention. For the reasons described above, combining the disclosure of Gelatos et al. with the disclosure of Landers et al. teaches away from the present invention. Therefore, applicants respectfully request withdrawal of the rejection of Claims 8 - 17 under 35 USC § 103(a) over Gelatos et al. in view of Landers et al.

Claims 8 - 17 and 21 - 26 are rejected under 35 USC § 103(a) as being unpatentable over Hoshino in view of Landers et al.

Hoshino et al. also describes a semiconductor device having a silicon substrate with a metal layer deposited over the silicon, followed by a barrier layer deposited over the metal, followed by copper deposited directly over the barrier layer. As described above with reference to Landers et al., this teaches away from applicants' invention in that it does not even suggest that the  $\langle 111 \rangle$  crystallographic content of the copper will be affected by deposition directly over the barrier layer.

Specifically, at Col. 3, lines 28 - 66, Hoshino describes depositing a metallic layer 20 (which may be Ti, Al or platinum), followed by a barrier metallic layer 22 (which may be selected from a laundry list including titanium nitride, tungsten, tungsten nitride, zirconium nitride, titanium carbide, tungsten carbide, tantalum, tantalum nitride, or titanium tungsten), followed by a copper metallization layer 24. Hoshino does not disclose or even suggest that one skilled in the art should first deposit  $TaN_x$ , followed by Ta, with copper deposited over the Ta, as taught by applicants.

At page 5 of the present Office Action, the Examiner states that "Applicant's latter argument is exactly what the rejection based on Hoshino in view of Landers was intended to render obvious

at least to one of ordinary skill in the art. A modification of the first layer in Hoshino's invention by employing its corresponding nitride would have been obvious to the skilled artisan because a Ta/TaN barrier layer combination is well-known and desired as an effective barrier layer for copper metallization."

Apparently it is not so obvious, since all of the references cited by the Examiner which pertain to the use of Ta in combination with TaN<sub>x</sub> show deposition of the Ta layer, followed by deposition of the TaN<sub>x</sub> layer, followed by deposition of the copper. In all of these cases, the crystalline structure of the copper will not be high in <111>, and as a result the electromigration properties of the copper will not be as good as those which will be obtained when applicants method of invention is used.

Further, the first metal layer materials recommended in the Hoshino reference did not include tantalum, but instead were limited to titanium, aluminum and platinum. As discussed in applicants' previous Amendment "A", either tantalum or tantalum nitride may be used as the second (barrier) layer material, according to the method disclosed by Hoshino. Hoshino does not recognize that tantalum is not a good barrier layer, and does not recognize that the copper crystallographic content is affected when the layer underlying the copper is tantalum nitride rather than tantalum.

Whether taken alone or in combination, the disclosures of Hoshino and Landers et al. neither teach nor suggest applicants' claimed invention. In light of the above arguments, applicants respectfully request withdrawal of the rejection of Claims 8 - 17 and 21 - 26 under 35 USC § 103(a) over Hoshino in view of Landers et al.

Claims 18 - 20 are rejected under 35 USC § 103(a) as being unpatentable over Gelatos et al., in combination with Landers et al., as applied to Claims 8 - 17, and further in view of Ngan.

Claims 18 - 20 and 27 are rejected under 35 USC § 103(a) as being unpatentable over Hoshino, in view of Landers et al., as applied to Claims 8 - 17, and further in view of Ngan.

The deficiencies of the disclosures of Gelatos et al., Landers et al., and Hoshino with respect to the patentability of the presently claimed invention have been discussed in detail above.

Ngan is cited by the Examiner as showing that in the manufacture of semiconductor devices, ion-deposition sputtering is preferred over traditional sputtering in order to have uniform step coverage and filling of contact hole vias. The Ngan reference pertains to a method of avoiding contamination from an induction coil during ionized sputtering. The only example materials mentioned are titanium and titanium nitride. One skilled in the art might decide to try to ion deposition sputter tantalum or tantalum nitride in view of the disclosure of Ngan, but it is well established in case law that "obvious to try" does not meet the requirement under 35 U.S.C. § 103 for obviousness. "The mere need for experimentation to determine parameters needed to make a device work is an application of the often rejected obvious-to-try standard and falls short of the statutory obviousness of 35 U.S.C. §103." (*Uniroyal Inc. v. Rudkin-Wiley Corp.*, 837 F.2d 1044, 5 U.S.P.Q.2d 1434 (Fed. Cir. 1988).) "An 'obvious-to-try' situation exists when a general disclosure may pique the scientist's curiosity, such that further investigation might be done as a result of the disclosure, but the disclosure itself does not contain a sufficient teaching of how to obtain the desired result or indicate that the claimed result would be obtained if certain directions were pursued." (*In re Eli Lilly & Co.*, 902 F.2d 943, 14 U.S.P.Q. 2d 1741 (Fed.Cir. 1990).)

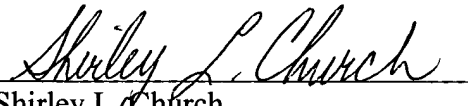
Even if one skilled in the art were to combine the disclosure of Ngan with the disclosures of Gelatos et. al. and Landers et al.; or Hoshino and Landers et al., the combination of the teachings would not make obvious applicants' invention, as one skilled in the art would not know that tantalum nitride makes a much better barrier layer than tantalum and that it is necessary to have tantalum (and not tantalum nitride) in contact with the overlying copper layer, so that the copper <111> content which provides improved electromigration resistance will be obtained.

Whether taken alone or in combination, none of the references cited above teaches or suggests applicants' claimed invention. In light of the above arguments, applicants respectfully request

withdrawal of the rejection of Claims 18 - 20 under 35 USC § 103(a) over Gelatos et al. in combination with Landers et al., and further in view of Ngan, as well as withdrawal of the rejection of Claims 18 - 20 and 27 under 35 USC § 103(a) over Hoshino in view of Landers et al., and further in view of Ngan.

Applicants believe that the claims as amended are in condition for allowance, and the Examiner is respectfully requested to enter the requested amendments and to pass the application to allowance. The Examiner is invited to contact applicants' attorney with any questions or suggestions, at the telephone number provided below.

Respectfully submitted,

  
Shirley L. Church  
Registration No. 31,858  
Attorney for Applicant  
(408) 975-7960

Correspondence Address:  
Patent Counsel  
Applied Materials, Inc.  
P.O. Box 450-A  
Santa Clara, CA 95052